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A strategy has been developed for the distribution of the constraint of large linear programs among parallel processors. New parallel algorithms for for multi-commodity flows problems have been developed.

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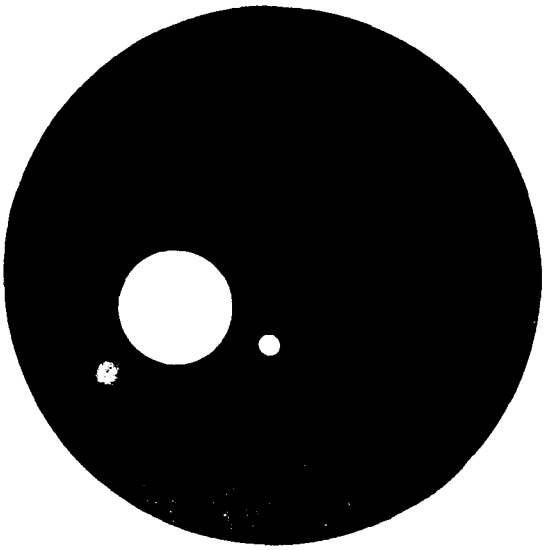
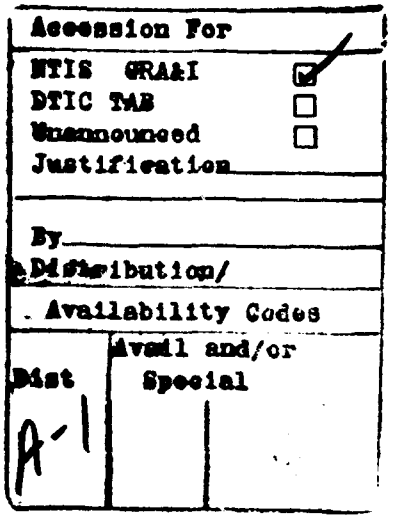


Final Report

for the Period

June 1, 1989 - September 30, 1993

CENTER FOR PARALLEL OPTIMIZATION



Final Report

for the Period

June 1, 1989 - September 30, 1993

1. Period 1

June 1, 1989 - May 31, 1990

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INTRODUCTION & SUMMARY

The Center for Parallel Optimization (CPO) was established June 1, 1989 with a grant from the Air Force Office of Scientific Research. Its primary purpose is to provide an appropriate environment, both physically and intellectually, for the conception, development and implementation of computational algorithms for the parallel solution of optimization and related problems. The CPO shares the facilities and services of both the Computer Sciences Department and the Center for the Mathematical Sciences. Its staff is made up of the Principal Investigators: Professors Olvi L. Mangasarian and Robert R. Meyer, and the Co-Investigators: Visiting Assistant Professor Renato De Leone and Assistant Professor Michael C. Ferris. This report summarizes the activities of the CPO during its first year of existence. These activities, described in the following sections, are as follows.

1. **Research Narrative.** Each of the four investigators describes informally his research achievements during the past year.

2. **CPO Reports & Papers.** A listing of 18 papers and reports written in the past year by the investigators and their Ph.D. students is given.

3. **Talks by CPO Staff.** Thirty four talks in the U.S. and abroad were given by the investigators and their Ph.D. students, most of them by invitation.

4. **CPO Ph.D. Students.** Ten Ph.D. graduate students were supported by the CPO faculty with CPO, NSF and UW funds.

5. **CPO Visitors & Speakers.** A total of 28 talks were given at Madison under the sponsorships of the CPO. Of these 13 were by outside visitors, both U.S. and foreign. These visitors spent varying periods of time at the CPO, between a minimum of 3 days to a maximum of 6 months. Some visitors came with their own funds, others were supported by the CPO.

1. RESEARCH NARRATIVE

R. De Leone

My research has resulted in new convergence conditions for partially asynchronous successive overrelaxation algorithms for linear complementarity problems. These conditions allows more efficient exploitation of parallel architectures.

I have implemented a fast parallel version of Lemke's algorithm on the Intel iPSC/2 which takes advantage of the vector capability of the machine and achieves near-linear speed-up for large-scale linear complementarity problems.

I have solved large multicommodity network optimization problems based on the Military Airlift Command PDS (Patient Distribution Model). A problem with 50,000 constraints and more than 150,000 variables (PDS-30) was solved in less than 17 hours on a DECSTATION 3100 with an absolute error accuracy of 0.1×10^{-5} in constraint satisfaction.

With Mangasarian, I have developed a strategy for distributing the constraints of large linear programs among parallel processors that will allow the solution of very large problems. We are currently testing the effectiveness of the method.

M. C. Ferris

My research interests are concerned with several current problems in mathematical programming, with particular emphasis on the theory of nonlinear programming and the implementation of efficient algorithms, both on serial and parallel architectures. The long-range goal of my research is to develop and implement stable algorithms to find global solutions of nonlinear programs and investigate the usefulness of probabilistic search methods. In order to achieve this, I have been investigating three main ideas which I believe will produce efficient computational methods.

The first of these are the so-called genetic algorithms, which I have applied to some general optimization problems. The particular emphasis of the research is to determine what factors affect a parallel implementation of the method. I have isolated several features of these approaches which makes it attractive for such implementation, including local neighborhoods. These ideas significantly reduce communication and synchronization penalties. A prototype asynchronous method based on these ideas is currently being tested.

I have been investigating the use of nonmonotone linesearch procedures in nonlinear programming codes. The use of nonmonotone linesearches enables steplengths of one to be taken much more frequently and in initial trials has led to considerable improvements over the traditional damping procedures. I am looking at ways of generalizing variants of Newton's method in order to effect the solution of nonsmooth equations. These are of particular interest for nonlinear complementarity problems, since there are several ways of formulating such problems as nonsmooth equations. Although the utility of parallelism is not so

apparent here, I feel that it can be employed sensibly in the solution of projection problems and for direction finding, and current work is being carried out to implement parallel equation solvers for use in these codes.

In recent work with Burke and Mangasarian, we have identified a property of a given problem, namely a weak sharp minimum, which results in a finite termination property by means of a simple modifying process involving the solution of a single linear program. This property has been investigated in relation to linear complementarity problems and nondegeneracy, with several existence results and equivalences established.

O. L. Mangasarian

Together with Dr. William H. Wolberg of the Department of Surgery at University of Wisconsin Hospitals and my Ph.D. student Rudy Setiono, I have used linear programming to develop software for the diagnosis of breast cancer. The software has been in use at the U.W. Hospitals for over a year with great success. Originally trained on 369 samples, the software diagnosed all of 70 subsequent cases correctly except one. At that time it was retrained and since then it has correctly classified all 31 subsequent cases.

With my student Kristin Bennett we have shown that a linear programming procedure for pattern recognition can be viewed as a neural network with a specific topology. The linear programming approach, when tested on medical diagnosis problems, and certain other problems outperforms the standard Back Propagation Algorithm of neural networks in speed of training, in determining the minimal number of hidden units, and in correctly classifying the training set. On testing sets it does as well or better than Back Propagation.

Matrix splitting is an effective way for parallelizing the solution of very large linear programs and nonlinear programs. Recently I established iterate convergence of a class of matrix splittings where the subproblems are solved inexactly. This approach when combined with a constraint distribution procedure that I have been developing together with De Leone, may yield a practical way of solving extremely large problems that cannot be handled by existing computer technology.

R. R. Meyer

My research under this grant has emphasized parallel algorithms for large-scale network optimization problems. Problems of this class arise in a variety of Air Force logistical applications.

In the area of single-commodity pure and generalized networks, my research with my Ph.D. student Rob Clark (now working for IBM in mathematical programming software development) led to the development of parallel versions of the network simplex method on the Sequent Symmetry S81 shared-memory multiprocessor. We collaborated with Jeff Kennington of SMU in testing some of these parallel algorithms in order to have a broad range of test problems and algorithms for comparison purposes. The codes developed under the CPO

grant were shown to be significantly faster than the well-known IBM code MPSX and other leading network flow codes. Particularly good speedups were obtained on very large generalized network flow problems of over 1 million variables, which were solved on the Sequent in just over 8 minutes. The multi-processor approach developed in this research for network flow problems also has promise for general linear programming problems, since it emphasizes the parallelism inherent in the simplex pricing operation.

A second area of my research in parallel algorithms for network flows has been multicommodity flows, where I have developed a decomposition approach combining a barrier function technique (associated with interior point methods) with a coordination step related to the well-known Dantzig-Wolfe method. This method has been proved to be convergent under some very general conditions, and has been demonstrated to be very effective in solving very large versions of the Air Force Patient Distribution System models. In fact, by using this algorithm we have been able to solve, with my Ph.D. students Gary Schultz and Jonathan Yackel, problems of this class that are much larger than those reported elsewhere. I am now investigating generalizations of this approach that are related to simplicial decomposition, and offer the possibility of accelerating convergence through the combination of multiple previous updates.

2. CPO REPORTS & PAPERS

1. R. De Leone: "Partially and totally asynchronous algorithms for linear complementarity problems", University of Wisconsin Computer Sciences Tech. Rpt. 888, November 1989, to appear, Journal of Optimization Theory and Applications.

2. R. De Leone & T. H. Ow: "Parallel implementation of Lemke's algorithm on the hypercube", University of Wisconsin Computer Sciences Tech. Rpt. 905, January 1990, submitted to ORSA Journal on Computing.

3. M. C. Ferris & O. L. Mangasarian: "Finite perturbation of convex programs", University of Wisconsin Computer Sciences Tech. Rpt. 802, October 1988, major revision March 1990, submitted to Applied Mathematics and Optimization.

4. J. V. Burke & M. C. Ferris: "Characterization of solution sets of convex programs", University of Wisconsin Computer Sciences Tech. Rpt. 851, June 1989, to appear in Operations Research Letters 9, 1990.

5. M. C. Ferris & O. L. Mangasarian: "Minimum principle sufficiency", University of Wisconsin Computer Sciences Tech. Rpt. 853, June 1989, to appear in Mathematical Programming A.

6. M. C. Ferris & M. Vlach: "Scheduling with earliness and tardiness penalties", University of Wisconsin Computer Sciences Tech. Rpt. 925, March 1990, submitted to Mathematics of Operations Research.

7. E. J. Anderson & M. C. Ferris: "Parallel genetic algorithms in optimization", Manuscript, March 1990, submitted to Proceedings of the Fourth SIAM convergence on Parallel Processing for Scientific Computing, Chicago.

8. E. J. Anderson & M. C. Ferris: "A genetic algorithm for the assembly line balancing problem", University of Wisconsin Computer Sciences Tech. Rpt. 926, March 1990, to appear in Proceedings of the Integer Programming Combinatorial Optimization Conference, Waterloo, Ontario, Canada, May 28-30, 1990.

9. M. C. Ferris & A. B. Philpott: "On affine scaling and semi-infinite programming", Manuscript, April 1990, submitted to Mathematical Programming A.

10. M. C. Ferris, L. Grippo & S. Lucidi: "A nonmonotone Gauss-Newton method for nonsmooth equations", Manuscript, May 1990.

11. W. H. Wolberg & O. L. Mangasarian: "Computer-aided diagnosis of breast cytology via two expert systems", October 1989, to appear, Analytical and Quantitative Cytology and Histology.

12. O. L. Mangasarian, R. Setiono & W. H. Wolberg: "Pattern recognition via linear programming: Theory and application to medical diagnosis", University of Wisconsin Computer Sciences Tech. Rpt. 878, September 1989, to appear, SIAM Workshop on Large-Scale Numerical Optimization, Cornell University, Ithaca, New York, October 19-20, 1989.

13. W. H. Wolberg & O. L.Mangasarian: "Computer-designed expert systems for breast cytology diagnosis", February 1990, submitted, American Medical Association Archives of Surgery.

14. O. L. Mangasarian: "On the convergence of iterates of an inexact matrix splitting algorithm for the symmetric monotone linear complementarity problem", University of Wisconsin Computer Sciences Tech. Rpt. 917, March 1990, submitted to SIAM Journal on Optimization.

15. R. H. Clark, J. Kennington, R. R. Meyer & M. Ramamurti: "Generalized networks: parallel algorithms and empirical analysis", University of Wisconsin Computer Sciences Tech. Rpt. 904, December 1989, submitted to ORSA Journal on Computing.

16. G. Schultz & R. R. Meyer: "A three-phase algorithm for block-structured optimization", University of Wisconsin Computer Sciences Tech. Rpt. 932, May 1990, submitted to Proceedings of Fourth SIAM Conference on Parallel Processing for Scientific Computing, Chicago.

17. R. H. Clark: "The efficient parallel solution of generalized network flow problems", University of Wisconsin Computer Sciences Tech. Rpt. 933, May 1990.

18. G. Schultz & R. R. Meyer: "Structured parallel interior point methods", University of Wisconsin Computer Sciences Tech. Rpt. 934, May 1990.

3. TALKS BY CPO STAFF

R. De Leone

1. "Parallel solution of very large linear complementarity problems and linear programs by asynchronous methods", SIAM Annual Meeting, San Diego, July 18, 1989.

2. "Parallel algorithms for linear complementarity problem", University of Salerno, Italy, August 31, 1989.

3. "Serial and parallel solution of large linear complementarity problems and linear programs", Argonne National Laboratory, Argonne, October 24, 1989.

4. "Partially and totally asynchronous algorithms for linear complementarity problems and linear programs", SIAM Conference on Parallel Processing for Scientific Computing, Chicago, December 11, 1989.

5. "Parallel implementation of Lemke's algorithm on the hypercube", SIAM Conference on Parallel Processing for Scientific Computing, Chicago, December 11, 1989.

M. C. Ferris

1. "Weak sharp minima and minimum principle sufficiency", Istituto Di Analisi dei Sistemi ed Informatica, Rome, July 1989.

2. "Genetic algorithms and the assembly line balancing problem", Istituto Di Analisi dei Sistemi ed Informatica, Rome, July 1989.

3. "Sharp functions in optimization", ORSA/TIMS Joint National Meeting, New York City, October 1989.

4. "A genetic algorithm for knapsack problems", SIAM Conference on Parallel Processing for Scientific Computing, Chicago, December 1989.

5. "Parallel genetic algorithms in optimization", Argonne National Laboratory, Argonne, March 1990.

6. "Parallel genetic algorithms in optimization", Mathematics Association of America, Richland Center, April 1990.

7. "Globally convergent methods for nonlinear complementarity problems", TIMS/ORSA Joint National Meeting, Las Vegas, May 1990.

8. "Genetic algorithms and the assembly line balancing problem", Integer Programming and Combinatorial Optimization Conference, Waterloo, Canada, May 1990.

O. L. Mangasarian

1. "Error bounds for nondegenerate monotone linear complementarity problems", International Conference on Parametric Optimization and Related Topics, Eisenach, East Germany, June 27 - July 2, 1989.

2. "Pattern separation via linear programming: Theory and an application to breast cancer diagnosis", University of Calabria, July 3, 1989.

3. "Computing the norm of a largest element of a bounded polyhedral set", University of Calabria, July 4, 1989.

4. "Asynchronous successive overrelaxation for linear complementarity problems and linear programs", University of Calabria, July 5, 1989.

5. "Finite perturbation of convex programs", University of Calabria, July 6, 1989.

6. "New error bounds for nondegenerate monotone linear complementarity problems", University of Calabria, July 7, 1989.

7. "Pattern separation via linear programming", IASI, Rome, July 11, 1989.

8. "Error bounds for nondegenerate monotone linear complementarity problems", IASI, Rome, July 13, 1989.

9. "Pattern separation by linear programming: Theory and an application to medical diagnosis", ORSA/TIMS Meeting, NYC, October 16-18, 1989.

10. "Pattern separation via linear programming: Theory and an application to breast cytology diagnosis", Cornell University, October 19-20, 1989.

11. "Interior proximal point solution of linear programs", SIAM Conference on Parallel Processing for Scientific Computing, Chicago, December 11-13, 1989.

12. "Linear programming in pattern recognition", US/USSR Seminar on Large-Scale Optimization, University of Maryland, College Park, January 9-12, 1990.

13. "Pattern recognition via mathematical programming", Second Asilomar Workshop on Progress in Mathematical Programming, Asilomar, California, February 5-7, 1990.

14. "Pattern recognition via linear programming: Theory and application to medical diagnosis", North Carolina State University, Raleigh, March 14, 1990.

15. "Pattern recognition via linear programming: Theory and application to medical diagnosis", Johns Hopkins University, Baltimore, March 15, 1990.

16. "Serial and parallel interior proximal point methods for linear programs", TIMS/ORSA Joint National Meeting, Las Vegas, May 1990.

R. R. Meyer

1. "A hybrid parallel algorithm for network optimization", SIAM National Meeting, San Diego, July 1989.

2. "A family of parallel algorithms for structured optimization", ORSA/TIMS National Meeting, New York, October 1989.

3. "A tri-partite algorithm for block-structured optimization", SIAM Conference on Parallel Processing for Scientific Computing, Chicago, December 1989.

4. "Parallel algorithms for large-scale network optimization", Mathematische Optimierung Conference-Oberwolfach, Germany, January 1990.

5. "Hybrid parallel algorithms for network flows", TIMS/ORSA National Meeting, Las Vegas, May 1990.

4. CPO PH.D. STUDENTS
SUPPORTED BY AFOSR, NSF & UW GRANTS

1. Kristin Bennett (Mangasarian)
2. Menglin Cao (Ferris)
3. Rob Clark (Meyer; Ph.D. granted 8/89)
4. Terence Ow (De Leone; until 12/89)
5. Stephen Palzewicz (De Leone)
6. Jun Ren (Mangasarian)
7. Gary Schultz (Meyer)
8. Rudy Setiono (Mangasarian)
9. Robert Welch (Ferris)
10. Jonathan Yackel (Meyer)

5. CPO VISITORS AND SPEAKERS

Jeff Kennington, Southern Methodist University, "An empirical evaluation of the KORBX algorithm for military airlift applications", June 6, 1989.

Robert S. Maier, University of Minnesota, "Partitioned linear programming", July 25, 1989.

Stephen Wright, North Carolina State University, "A parallel algorithm for banded systems, with application to discrete time optimal control", August 16, 1989.

Dimitri Bertsekas, Massachusetts Institute of Technology, "Auction algorithms for linear network flow problems", September 28, 1989.

Michael Todd, Cornell University, "A probabilistic model for linear programming", October 11, 1989.

Michael Todd, Cornell University, "A large-step primal-dual affine algorithm for linear programming", October 12, 1989.

Laure Escudero, IBM Yorktown Heights Research Center, "Coefficient reduction methods for 0-1 programs", October 12, 1989.

Richard Karp, University of California at Berkeley, "Recent development in the probabilistic analysis of combinatorial algorithms", November 8, 1989.

Richard Karp, University of California at Berkeley, "The *k*-server problem", November 9, 1989.

Leonid Khachiyan, USSR Academy of Sciences, Moscow, "Centers of solids and optimal algorithms for convex programming", November 15, 1989.

Alexander Schrijver, Mathematical Center, Amsterdam, The Netherlands, "Polyhedral algorithms in combinatorial optimization", November 21, 1989.

Alexander Schrijver, Mathematical Center, Amsterdam, The Netherlands, "Homotopy algorithms for VLSI routing", November 22, 1989.

Iain S. Duff, Harwell Laboratories, Oxfordshire, England, "Recent developments in sparse matrix research", December 6, 1989.

Iain S. Duff, Harwell Laboratories, Oxfordshire, England, "The solution of large-scale least-squares problems on supercomputers", December 7, 1989.

Andrew Philpott, University of Auckland, New Zealand, "Continuous network programming", January 15, 1990.

Andrew Philpott, University of Auckland, New Zealand, "Rostering staff using assignment algorithms", January 18, 1990.

Michael Ferris, University of Wisconsin, Madison, "Trust regions and line searches", February 1, 1990.

Renato De Leone, University of Wisconsin, Madison, "Parallel implementation of Lemke's algorithm on the hypercube", February 8, 1990.

Robert R. Meyer, University of Wisconsin, Madison, "Obtaining feasible points for multicommodity problems", February 15, 1990.

Milan Vlach, Charles University, Prague, "On aggregation in mathematical programming", February 22, 1990.

Yannis E. Ioannidis, University of Wisconsin, Madison, "Randomized algorithms for query optimization", March 1, 1990.

Gary L. Schultz, University of Wisconsin, Madison, "(Strongly) polynomial algorithms for the minimum cost flow problem", March 8, 1990.

Michael C. Ferris, University of Wisconsin, Madison, "Parallel genetic algorithms in optimization", March 15, 1990.

Fernando Alvarado, University of Wisconsin, Madison, "Sparse matrix inverse factors", March 29, 1990.

Danny Ralph, University of Wisconsin, Madison, "Nonsmooth Newton's method in nonlinear programming", April 12, 1990.

Olvi L. Mangasarian, University of Wisconsin, Madison, "Convergence of iterates of an inexact matrix splitting algorithm for the symmetric monotone linear complementarity problem", April 26, 1990.

Xiangqian Wu, University of Wisconsin, Madison, "Optimized diagnostic scheme for parameterizing fractional cloud cover in numerical weather prediction model", May 3, 1990.

Ubaldo Garcia-Palomares, Universidad Simon Bolivar, "A new approach for solving large structured system of linear (in)equalities", May 15, 1990.

2. Period 2

June 1, 1990 - September 30, 1991

INTRODUCTION & SUMMARY

This report describes the continuing research at the Center for Parallel Optimization (CPO). The center was established June 1, 1989 with a grant from the Air Force Office of Scientific Research. Its primary purpose is to provide an appropriate environment, both physically and intellectually, for the conception, development and implementation of computational algorithms for the parallel solution of optimization and related problems. The CPO shares the facilities and services of both the Computer Sciences Department and the Center for the Mathematical Sciences. Its staff is made up of the Principal Investigators: Professors Olvi L. Mangasarian and Robert R. Meyer, and the Investigators: Visiting Assistant Professor Renato De Leone and Assistant Professor Michael C. Ferris. This report summarizes the continuing activities of the CPO during the 16-month period of June 1, 1990 to September 30, 1991. Their activities, described in the following sections, are as follows.

1. **Research Narrative.** Each of the four investigators describes informally his research achievements during the 16 months covered by this report.

2. **CPO Reports & Papers.** A listing of 35 papers and reports written in the 16 months covered by this report by the investigators and their Ph.D. students is given.

3. **Talks by CPO Staff.** Forty talks in the U.S. and abroad were given by the investigators and their Ph.D. students, most of them by invitation.

4. **CPO Ph.D. Students.** Twelve Ph.D. graduate students were supported by the CPO faculty with CPO, NSF and UW funds.

5. **Symposium on Parallel Optimization 2.** This 3-day symposium was held in Madison July 23-25, 1990, with 20 invited speakers. Refereed proceedings of the symposium have appeared as Volume 1, Number 4 of the SIAM Journal on Optimization in November of 1991.

6. **CPO Visitors & Speakers.** Over 35 people visited the Center during the 16 months covered by this report. These visitors spent varying periods of time at the CPO, a minimum of 3 days to a maximum of 6 months. Some visitors came with their own funds; others were supported by the CPO.

7. **Acquisition of CM-5 supercomputer.** All four CPO faculty members participated in a 1990 equipment proposal to NSF for new parallel computers for the Computer Sciences Department. This proposal was funded in 1991 at the level of $2,000,000 plus additional matching funds from the College of Letters and Science and the Graduate School. The first supercomputer acquired with this funding was a Thinking Machines Corporation CM-5 with 64 processors, installed in September, 1991.

1. RESEARCH NARRATIVE

R. De Leone

My research under this grant has focused on the following areas: parallel solution of large-scale linear and quadratic programs, parallel solution of 0-1 knapsack problems and integer programming formulation of problems in high-level synthesis for VLSI design.

In the area of parallel solution of large scale optimization problems I focused my attention on two important classes of problems: multicommodity network optimization problems and quadratic programs with simple bounds. Using successive overrelaxation (SOR) algorithms I was able to solve the Military Airlift Command PDS (Patient Distribution Model) problems. The largest problem solved in this class (PDS-40) has more than 60,000 constraints and 210,000 variables. On a IBM RISC 6000 POWERstation, a solution was obtained in less than 3.5 hours with seven-figure accuracy in constraint satisfaction.

Extremely large quadratic programs with simple bounds were also solved by using SOR techniques on two massively parallel supercomputers: the Connection machine CM-2 and the MasPar MP-1. On the 16,384-processor MasPar MP-1 a problem with more than 9,000,000 variables was solved in less than 2 hours. By comparison, the largest problem in this class solved by Karmarkar-type interior point algorithms involved less than 500,000 variables and required more than 2.5 hours on a large IBM mainframe.

In the area of parallel solution of 0-1 knapsack problems, I concentrated on massively parallel algorithms based on dynamic programming. Problems with as many 100,000 variables were solved and near-linear speedups were achieved.

Finally, in the area of VLSI design, we formulated the binding and allocation process for high-level synthesis as a 0-1 integer program. As far as we know this is the first attempt to provide a complete mathematical formulation for this problem. We successfully tested our approach on small problems. However, the number of variables and constraints quickly grows. We plan to use parallel branch-and-bound algorithms as well as parallel heuristic techniques to solve larger problems.

M. C. Ferris

My research under this grant has focused on the following two areas: parallel constraint distribution for nonlinear programs and genetic algorithms.

In my work on parallel constraint distribution with Mangasarian, we showed how to split the constraints of a nonlinear program among several processors and achieve fast practical convergence. A convergence theory was developed from operator splitting theory and an implementation of the method showed that this technique produced a solution to a given problem in small numbers of iterations independent of the number of processors used. To our knowledge, this is the first time that such a result has been claimed and has led to renewed

interest in such techniques.

I have isolated the important properties of genetic algorithms and the framework in which such methods should be used. The use of local neighborhoods in these methods on an Intel hypercube enabled me to significantly reduce communication times without degrading the solutions at all. Particular applications have been investigated, namely assembly line balancing and database query optimization.

In other related work, I have been investigating the use of path search techniques for general variational inequalities. In order to produce a practical code for such problems, I have been developing a code to run within the GAMS modelling environment. This will enable many economists and engineers to formulate and solve their models in a complementarity framework. As a constituent part of this work, I have developed a pivotal code to solve affine variational inequalities which is currently being used at Cornell University and the University of Washington.

O. L. Mangasarian

My research has focused on three areas: mathematical programming and neural networks, parallel optimization and error bounds.

In the neural network application area, our working neural diagnostic program at University of Wisconsin Hospitals has continued to diagnose breast cancer at a cumulative correctness rate of 98%. We have come up with practical, computational and theoretical enhancements that have improved the generalization capability of our diagnostic neural net. We have also solved a long-standing problem of approximately separating two disjoint point sets in n-dimensional real space with intersecting convex hulls by reducing it to a single linear program which is guaranteed to solve the problem without any modification.

In parallel optimization together with Ferris we have come up with an efficient procedure for distributing constraints among parallel processors in order to reduce problem size and introduce parallelism into our algorithm. Preliminary results are very encouraging. Along those lines I have also come up with an inexact matrix splitting method for solving the symmetric linear complementarity problem. This is a fundamental problem which underlies many optimization problems, including linear programming. The proposed algorithm is capable of solving extremely large problems both on serial and parallel processors.

In my ongoing research on error bounds, I have been interested in obtaining new and more effective bounds which allow us to gauge how good is an arbitrary point, for example one generated by any algorithm, by bounding its distance from the solution set. Such bounds are essential for terminating algorithms. They are also essential for designing fast algorithms. We have obtained a number of such bounds for various classes of optimization problems, some of which may lead to new and more powerful methods of solution.

R. R. Meyer

My research under this grant has emphasized parallel algorithms for large-scale network optimization problems and optimal methods for allocating data among parallel processors. Problems of the first type arise in a variety of Air Force logistical applications, and the research in the second area was motivated by a large-scale database application.

Under my direction, Gary Schultz, a research assistant supported by the CPO grant, recently completed his Ph.D. thesis in parallel algorithms for multi-commodity flows and other block-structured problems. This research led to the development of a decomposition approach combining a barrier function technique (associated with interior point methods) with a coordination step based on the solution of a low-dimensional nonlinear optimization problem. Novel aspects include generation of a feasible solution in a finite number of iterations (under very mild assumptions on the structure of the feasible set) and proof of convergence of asynchronous parallel variants of the basic method. In addition, this approach has been demonstrated to be very effective in solving very large versions of the Air Force Patient Distribution System models. In fact, by using this algorithm we have been able to solve on the Sequent multiprocessor problems of this class that are much larger than those reported in the literature. This technique will also provide an excellent vehicle for future research involving hybrid parallelism, in which certain tasks (for example, the solution of linear subproblems) are handled in data parallel mode using massive parallelism, whereas others (coordination steps) are treated via control parallelism at the same time, using the unique ability of the CM-5 to support both parallel paradigms.

In my second major area of research, the focus is on problems in which data or variables may be regarded as corresponding to a domain comprised of square, cubical, or hypercubical cells. Each cell corresponds to a task, and the problem is to allocate the cells among the processors of a parallel computer in such a way as to balance the loads among the processors while minimizing total communication between processors. By reformulating this problem in geometric terms, we were able to develop a procedure that generates optimal solutions for many problem subclasses and provides good lower bounds in the general case. Research is continuing on extensions beyond the original database application to problems of domain decomposition and to different models of interprocessor communication.

2. CPO REPORTS & PAPERS

1. R. De Leone: "Partially and totally asynchronous algorithms for linear complementarity problems", Journal of Optimization Theory and Applications, 69, 2, 235-249, 1991.

2. R. De Leone & T. H. Ow: "Parallel implementation of Lemke's algorithm on the hypercube", ORSA Journal on Computing, 3, 1, 1991.

3. R. Cerulli & R. De Leone & M. Gaudioso, R. Mautone: "Balanced solution to class of generalized set covering", University of Wisconsin Computer Sciences Technical Report #969, 1990, submitted to Naval Research Logistics.

4. R. De Leone & R. Jain: "Optimal resource allocation and binding of non-pipelined design" University of Wisconsin Computer Sciences Technical Report # 972, 1990.

5. R. De Leone & R. Jain & K. Straus: "Solution of multiple choice knapsack problems encountered in high-level synthesis of VLSI circuits", University of Wisconsin Computer Sciences Technical Report #980, 1990, submitted to International Journal of Computer Mathematics.

6. R. De Leone & M. Tork Roth: "Massively Parallel Solution of Quadratic Program via Successive Overrelaxation", University of Wisconsin Computer Sciences Technical Report # 1041, 1991, submitted to Concurrency Practice and Experience.

7. R. De Leone & R. Jain & M. Rim: "Optimal allocation and binding in High-level synthesis of VLSI digital systems" University of Wisconsin Department of Electrical and Computer Engineering, Technical Report # ECE-91-6, 1991, submitted to Mathematical Programming.

8. M.C. Ferris: "Finite Termination of the Proximal Point Algorithm", Mathematical Programming, 50(3), 359-366, 1991.

9. M.C. Ferris & O.L. Mangasarian: "Finite Perturbation of Convex Programs", Applied Mathematics and Optimization, 23(3), 263-273, 1991.

10. J.V. Burke & M.C. Ferris: "Characterization of Solution Sets of Convex Programs", Operations Research Letters 10, 57-60, 1991.

11. M.C. Ferris & O.L. Mangasarian: "Minimum Principle Sufficiency", University of Wisconsin Computer Sciences Technical Report # 853, 1989, to appear in Mathematical Programming.

12. M.C. Ferris & M. Vlach: "Scheduling with Earliness and Tardiness Penalties", University of Wisconsin Computer Sciences Technical Report # 925, 1990, to appear

in Naval Research Logistics Quarterly.

13. M.C. Ferris & A.B. Philpott: "On Affine Scaling and Semi-Infinite Programming", Manuscript, to appear in Mathematical Programming.

14. J.V. Burke & M.C. Ferris & M. Qian: "On the Clarke Subdifferential of the Distance Function to a Closed Set" ,Manuscript, to appear in Journal of Mathematical Analysis and Applications.

15. M. Cao & M.C. Ferris: "Genetic Algorithms in Optimization", Journal of Undergraduate Mathematics and its Applications, 12(1), 81-90,1991.

16. M.C. Ferris & O.L. Mangasarian "Parallel Constraint Distribution", SIAM Journal on Optimization 1(4), 487-500, 1991.

17. K. Bennett & M.C. Ferris & Y.E. Ioannidis: "A Genetic Algorithm for Database Query Optimization", Proceedings of the Fourth International Conference on Genetic Algorithms and Applications, Morgan Kaufman, San Mateo, CA, 1991.

18. M.C. Ferris "Parallel Constraint Distribution for Convex Quadratic Programs", University of Wisconsin Computer Sciences Technical Report # 1009, 1991, submitted to Mathematics of Operations Research.

19. M.C. Ferris & S. Lucidi: "Globally Convergent Methods for Nonlinear Equations", University of Wisconsin Computer Sciences Technical Report # 1030, 1991.

20. E.J. Anderson & M.C. Ferris: "Genetic Algorithms for Combinatorial Optimization: The Assembly Line Balancing Problem", Management Studies Research Paper 11/91, Engineering Department, University of Cambridge, 1991, submitted to ORSA Journal on Computing.

21. J.V. Burke & M.C. Ferris: "Weak Sharp Minima in Mathematical Programming", University of Wisconsin Computer Sciences Technical Report # 1050, 1991, submitted to SIAM Journal on Control and Optimization.

22. M.C. Ferris & O.L. Mangasarian: "Error Bounds and Strong Upper Semicontinuity for Monotone Affine Variational Inequalities", University of Wisconsin Computer Sciences Technical Report # 1056, 1991, submitted to Annals of Operations Research.

23. O.L. Mangasarian & W.H. Wolberg: "Computer-aided diagnosis of breast cytology via two expert systems", Analytical and Quantitative Cytology and Histology 12, 1990, 314-320.

24. O.L. Mangasarian: "On the convergence of iterates of an inexact matrix splitting algorithm for the symmetric monotone linear complementarity problem", SIAM Journal on Optimization 1, 1991, 114-122.

25. K.P. Bennett & O.L. Mangasarian: "Neural network training via linear programming", University of Wisconsin Computer Sciences Technical Report # 948, 1990, to appear in P. M. Pardalos (Editor), "Advances in Optimization and Parallel Computing", North Holland, Amsterdam 1992.

26. O.L. Mangasarian & W.H. Wolberg: "Cancer diagnosis via linear programming", SIAM News 23(5), September 1990, pp. 1 & 18.

27. O.L. Mangasarian: "Mathematical programming musings", in "History of mathematical programming", J. K. Lenstra, A. H. G. Rinnooy Kan and A. Schrijver, editors, North Holland, Amsterdam 1991, 107-113.

28. O.L. Mangasarian: "Global error bounds for monotone affine variational inequality problems", University of Wisconsin Computer Sciences Technical Report # 998, 1991, to appear, Linear Algebra and Its Applications.

29. K.P. Bennett & O.L. Mangasarian: "Robust linear programming discrimination of two linearly inseparable sets", University of Wisconsin Computer Sciences Technical Report # 1054, 1991, submitted, Optimization Methods and Software.

30. R. Clark & J. Kennington & R. Meyer &M. Ramamurti: "Generalized Networks: Parallel Algorithms and an Empirical Analysis" University of Wisconsin Computer Sciences Technical Report # 904, 1989, to appear in the ORSA Journal on Computing, 1991.

31. R. Meyer & Gary Schultz: "A Structured Interior Point Method", SIAM J. on Optimization, 1, 583-602, 1991.

32. S. Ghandeharizadeh & R. Meyer & G. Schultz & J. Yackel: "Optimal Balanced Partitions and a Parallel Database Application", University of Wisconsin Computer Sciences Technical Report # 986, 1990.

33. S. Ghandeharizadeh & R. Meyer & G. Schultz & J. Yackel: "Optimal Processor Assignment for Parallel Database Design" University of Wisconsin Computer Sciences Technical Report # 1022, 1991, to appear in Proceedings of the Fifth SIAM Conference on Parallel Processing for Scientific Computing.

34. R. Meyer & J. Yackel: "Optimal Tilings for Parallel Database Design" to appear in Advances in Optimization and Parallel Computing, North-Holland, 1992.

35. R. Meyer & J. Yackel: "Minimum-Perimeter Domain Decomposition", submitted to Special Issue of Mathematical Programming B on Applications of Discrete Optimization in Computer Sciences, 1991.

3. TALKS BY CPO STAFF

R. De Leone

1. "Parallel Solution of Complementarity Problems Using Lemke's Algorithm" International Conference on Parallel Computing, Capri, Italy, June 1990.

2. "Parallel Solution of Complementarity Problems Using Lemke's Algorithm" Universita' della Calabria, Rende, Italy, June 1990.

3. "Parallel Solution of Complementarity Problems Using Lemke's Algorithm", Universita' di Salerno, Salerno, Italy, June 1990.

4. "Parallel Asynchronous Methods for Large Sparse Linear Programs and Linear Complementarity Problems" Universita' di Salerno, Salerno, Italy, June 1990.

5. "Parallel Proximal Decomposition of Linear Programming Constraints" SIAM Annual Meeting, Chicago, July 1990.

6. "The Solution Large-Scale Networks by Successive Overrelaxation" SIAM Annual Meeting, Chicago, July 1990.

7. "Serial and Parallel Solution of Large-Scale Multicommodity Network" Symposium on Parallel Optimization 2, Madison, July 1990.

8. "Parallel Iterative Methods for Multicommodity Network Optimization Problems" ORSA/TIMS Joint National Meeting, Philadelphia October, 1990.

9. "Parallel Solution of 0-1 Knapsack Problems", Thinking Machines Corporation, Cambridge, Massachusetts, April, 1991.

10. "Serial and Parallel Solution of Large Scale Optimization Problems", Thinking Machines Corporation, Cambridge, Massachusetts, April, 1991.

M. C. Ferris

1. "Operator splitting and constraint distribution", Istituto Di Analisi dei Sistemi ed Informatica del CNR, Rome, June 1990.

2. "Parallel genetic algorithms for combinatorial optimization", Institute of Management Studies, Cambridge, England; July 1990.

3. "Parallel constraint distribution for convex programs", Symposium on Parallel Optimization 2, Madison, July 1990.

4. "Parallel constraint distribution for convex programs", ORSA/TIMS Joint National

Meeting, Philadelphia; October 1990.

5. "Genetic algorithms for combinatorial optimization", Advanced Computing Research Institute, Cornell University, Ithaca, New York; March 1991.

6. "Parallel constraint distribution", Center for Applied Mathematics, Cornell University, Ithaca, New York; March 1991.

7. "Parallel constraint distribution", 14th International Symposium on Mathematical Programming, Amsterdam; August 1991.

8. "Genetic algorithms for combinatorial optimization", TIMS/ORSA Joint National Meeting, Nashville; May 1991.

9. "Globally convergent methods for nonlinear equations", TIMS/ORSA Joint National Meeting, Nashville; May 1991.

10. "Generalized Gauss-Newton methods", Workshop on algorithms and applications of economic equilibrium models, London, Ontario; June 1991.

11. "A Gauss-Newton method for nonsmooth equations", International Conference on Applied Mathematics, Washington; July 1991.

12. "Pivotal methods for affine variational inequalities", 14th International Symposium on Mathematical Programming, Amsterdam; August 1991.

O. L. Mangasarian

1. "Parallel proximal point decomposition of linear programming problems", SIAM Annual Meeting, Chicago, July 1990.

2. "Nondegenerate monotone linear complementarity problems", ORSA/TIMS Joint National Meeting, Philadelphia October, 1990.

3. "Parallel distribution of nonlinear programming constraints', ORSA/TIMS Joint National Meeting, Philadelphia October, 1990.

4. "Cancer diagnosis via linear programming", Invited Talk, Schlumberger-Doll Research, Ridgefield, Connecticut, November, 1990.

5. "Inexact splitting methods for the symmetric monotone linear complementarity problem", TIMS/ORSA Joint National Meeting, Nashville, May, 1991.

6. "Neural network training via linear programming with application to medical diagnosis", TIMS/ORSA Joint National Meeting, Nashville, May, 1991.

7. "Neural network training via linear programming with application to medical

diagnosis", Thinking Machines Corporation, Cambridge, Massachusetts, May, 1991.

8. "Neural network training by mathematical programming", 14th International Symposium on Mathematical Programming, Amsterdam, Netherlands, August, 1991.

9. "Neural network training by mathematical programming", Humboldt University of Berlin, Germany, August, 1991.

R. R. Meyer

1. "Parallel optimization of large-scale networks", International Conference on Parallel Computing, Capri, Italy, June 1990.

2. "A tri-partite method for multicommodity flows", SIAM Annual Meeting, Chicago, July 1990.

3. "Serial and parallel solution of large-scale multicommodity networks", Symposium on Parallel Optimization 2, Madison, July 1990.

4. "Optimal balanced partitions and a parallel database application", The Wharton School, University of Pennsylvania, Philadelphia, October 1990.

5. "Structured interior point methods for multicommodity flows", TIMS/ORSA Joint National Meeting, Philadelphia, October 1990.

6. "Parallel computation and network flows", Distinguished Lecture Series in Management Science/Operations Research, University of Texas, Austin, November, 1990.

7. "Optimal balanced assignments and a parallel database application", Fifth SIAM Conference on Parallel Processing for Scientific Computing, Houston, March 1991.

8. "Optimal parallel task assignment for rectangular arrays", Fourteenth International Symposium on Mathematical Programming, Amsterdam, August 1991.

3. CPO Ph.D. STUDENTS
SUPPORTED BY AFOSR, NSF & UW GRANTS

1. Kristin Bennett (Mangasarian)
2. Menglin Cao (Ferris)
3. Chunhui Chen (Mangasarian)
4. Stephen Dirkse (Ferris)
5. Stephen Palzewicz (De Leone, until 12/90)
6. Jun Ren (Mangasarian)
7. Gary Schultz (Meyer, Ph.D. final oral on 9/91)
8. Mikhail V. Solodov (Mangasarian)
9. William Nick Street (Mangasarian)
10. Mary Tork Roth (De Leone)
11. Robert Welch (Ferris, until 5/91)
12. Jonathan Yackel (Meyer)

5. SYMPOSIUM ON PARALLEL OPTIMIZATION 2

With CPO support, a Symposium on Parallel Optimization in Madison was held during July 23-25, 1990. As was the case for the first Symposium on Parallel Optimization held in Madison August 10-12, 1987, refereed proceedings of this Symposium were published. For the Symposium on Parallel Optimization 2 the proceeding were published as Volume 1, Number 4 of the SIAM Journal on Optimization in November of 1991. This volume was edited by O.L. Mangasarian and R.R. Meyer. Its table of contents is reproduced below.

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6. CPO VISITORS AND SPEAKERS

James M. Ortega, University of Virginia, "Preconditioned conjugate gradient methods for elliptic boundary value problems", SPO2, July 23-25, 1990.

Ahmed Sameh & Randall Bramley, University of Illinois, "Projection methods for solving sparse nonsymmetric linear systems on multiprocessors", SPO2, July 23-25, 1990.

Stephen J. Wright, Argonne National Laboratory,"Partitioned dynamic programming", SPO2, July 23-25, 1990.

Layne T. Watson & Alexander P. Morgan, Virginia Polytechnic Institute & State University, "Serial and parallel global optimization of polynomial programs via homotopy algorithms", SPO2, July 23-25, 1990.

Ben Rosen, R. S. Maier & J. H. Glick, University of Minnesota, "Parallel solution of large-scale, block-angular concave programs", SPO2, July 23-25, 1990.

Russell A. Rushmeier & George L. Nemhauser, Georgia Institute of Technology, "A cooperating multiple search approach for parallel integer programming", SPO2, July 23-25, 1990.

Laurence C. W. Dixon, Numerical Optimisation Centre, "On parallel truncated Newton and variable metric algorithms", SPO2, July 23-25, 1990.

Stephen G. Nash & Ariela Sofer, George Mason University, "A practical truncated-Newton method for parallel optimization", SPO2, July 23-25, 1990.

Stavros A. Zenios, Wharton School, University of Pennsylvania, "Massively parallel network optimization with a financial application", SPO2, July 23-25, 1990.

Renato De Leone & Robert R. Meyer, University of Wisconsin, "Serial and parallel solution of large-scale multicommodity networks",SPO2, July 23-25, 1990.

Dimitri P. Bertsekas, M.I.T., "Parallel forward path search: A new dual coordinate ascent algorithm for shortest paths", SPO2, July 23-25, 1990.

Richard S. Barr & William Stripling, Southern Methodist University, "Parallel approaches to fixed charge network problems", SPO2, July 23-25, 1990.

John E. Dennis, Jr. & Virginia Torczon, Rice University, "Direct search methods for parallel machines", SPO2, July 23-25, 1990.

Paul Tseng, M.I.T., "On the rate of convergence of partially asynchronous gradient algorithms", SPO2, July 23-25, 1990.

Michael C. Ferris & Olvi L. Mangasarian, University of Wisconsin, "Parallel distribution

of convex programming constraints", SPO2, July 23-25, 1990.

Yurii E. Nestorov & Arkadii S. Nemirovsky, USSR Academy of Sciences, "Acceleration of interior point methods for linear programming with the aid of parallel computations", SPO2, July 23-25, 1990.

Dirk Van Gucht, Indiana University, "Parallel genetic algorithms applied to the traveling salesman problem", SPO2, July 23-25, 1990.

Heinz Mühlenbein, GMD, Germany "Parallel genetic algorithms and combinatorial optimization", SPO2, July 23-25, 1990.

John J. Grefenstette, Naval Research Laboratory, "Parallel search with genetic algorithms", SPO2, July 23-25, 1990.

Donald E. Brown & Christopher L. Huntley, University of Virginia, "Parallel genetic algorithms as control structures for local optimizers", SPO2, July 23-25, 1990.

David Kuck, University of Illinois, "Delivering parallel performance", September 28, 1990.

Allan Gottlieb, New York University, "Processor to memory interconnection networks", October 10, 1990.

Arvind, Massachusetts Institute of Technology, "Advances in dataflow architectures: the Monsoon project", October 17, 1990.

John Hennessy, Stanford University, "Scalable shared-memory multiprocessors and the Stanford Dash architecture", October 24 1990.

H. T. Kung, Carnegie Mellon University, "Parallel architectures and gigabit networks", October 31, 1990.

Bob Rau, Hewlett Packard Laboratories, "Extracting and exploiting instruction level parallelism", November 7, 1990.

Jean-Loup Baer, University of Washington, "Cache management in shared- memory multiprocessors", November 14, 1990.

Tom Luo, Mc Master University, "Error bound and convergence of iterative methods for monotone affine variational inequalities", April 10, 1991.

Raffaele Cerulli, University of Salerno, Salerno, Italy, January 1991-May 1991.

Mo Bazaraa, American Airlines Decision Technologies, July 16-17, 1991.

David Rumelhart, Stanford University, "Learning and generalization in connectionist AI", September 11, 1991.

Tom Mitchell, Carnegie-Mellon University, "User interfaces that learn", September 25, 1991.

7. Acquisition of CM-5 supercomputer

In September 1990, the CPO faculty members participated in an equipment proposal to the NSF Institutional Infrastructure program for the acquisition of new parallel computers for the Computer Sciences Department. This proposal was funded in 1991 at the level of $2,000,000 plus additional matching funds from the College of Letters and Science and the Graduate School. The first supercomputer acquired with this funding was a Thinking Machines Corporation CM-5 with 64 processors, installed in the Computer Sciences Department in September, 1991. Our department was one of only a handful of groups to obtain the CM-5 in its widely publicized initial distribution in September. This computer architecture is the first to attain one of the major computing goals of this century-scalability to teraflop computing rates. Each processor in the system will deliver up to 128 megaflops, and the architecture is designed to efficiently support configurations of thousands of processors. The CM-5 is also the first machine with the capability of supporting both major parallel computing paradigms-data parallelism, in which data is distributed among processors which subsequently execute the same instruction or set of instructions between synchronized communication steps, and control parallelism, in which processors may execute completely different programs and communicate asynchronously. As described in the research narratives of Section 1, for a broad variety of applications the four CPO faculty are developing and implementing methods that utilize both of these forms of parallelism. Thus, the CM-5 offers the unique opportunity to experiment with both parallel modes on the same supercomputer, as well as to efficiently implement hybrid parallel algorithms that have some subtasks that can utilize data parallelism and other subtasks for which control parallelism is more appropriate.

3. Period 3

October 1, 1991 - September 30, 1993

3 Activities

3.1 Research Areas of Investigators

O.L. Mangasarian

- Mathematical Programming in Neural Networks (with Kristin P. Bennett)
- Neural Networks in Medical Diagnosis and Prognosis (with Kristin P. Bennett, W. Nick Street and William H. Wolberg)
- Parallel Constraint and Variable Distribution (with Michael C. Ferris)
- Error Bounds in Mathematical Programming (with Michael C. Ferris and Jun Ren)
- Nonlinear Programming as Unconstrained Optimization (with Mikhail V. Solodov)
- General Convergence Theory for Unconstrained Parallel Optimization
- Generalized Complementarity Problems

R.R. Meyer

- Tiling for Optimal Parallel Domain Decomposition
- Barrier-based Decomposition for Large-Scale Optimization
- Resource-directed Multicommodity Optimization (with R. De Leone)
- Operator-splitting for Parallel Optimization (with R. De Leone)

M. C. Ferris

- Parallel Variable and Constraint Distribution (with O.L. Mangasarian and J. Horn)
- Operator Splitting Methods (with J. Eckstein)
- Callable Program Library (with S. Dirkse and T. Rutherford)
- Nonmonotone line search (with S. Lucidi)
- Gauss-Newton Methods for Complementarity Problems (with D. Ralph, J. Burke and L. Qi)
- Solution methods for Affine Variational Inequalites (with M. Cao and S. Billups)
- Weak Sharp Minima (with J. Burke and O.L. Mangasarian)

R. De Leone

- Massively Parallel Solution of Linear and Quadratic Network Flow Problems.
- Resource-directed Multicommodity Optimization (with R. Meyer).
- Serial (with R. Cerulli) and Parallel Auction Algorithms for Network Flow Problems (with P. Tiwari and B. Narendran).
- Optimization problems in radioterapy cancer treatment (with J. Deasy and T. Mackie).

3.2 Research Assistants

O.L. Mangasarian

- **Kristin P. Bennett**, Air Force Fellow: "Machine learning via mathematical programming", Ph.D. granted August 1993.
- **Jun Ren**, NSF Support: "Computable error bounds in mathematical programming", Ph.D. granted August 1993.
- **W. Nick Street**, AFOSR Support: "Medical diagnosis and prognosis via machine learning and mathematical programming", Ph.D. expected August 1994.
- **Chunhui Chen** , AFOSR-NSF Support: "Serial and parallel smoothing methods in mathematical programming", Ph.D. expected August 1995.
- **Mikhail V. Solodov**, TA and AFOSR Partial Support: "Serial and parallel optimization methods in neural networks", Ph.D. expected August 1995.

R.R. Meyer

- **Jonathan Yackel**, AFOSR Support: "Tiling for Optimal Parallel Domain Decomposition", Ph.D. granted May 1993.
- **Spyros Kontogiorgis**, AFOSR Partial Support: "Data-Parallel Decomposition Methods", Ph.D. expected May 1994.
- **Armand Zakarian**, AFOSR Partial Support: "Parallel Algorithms for Separable Quadratic Network Optimization", Ph.D. expected August 1994.
- **Golbon Zakeri**, NSF Partial Support: "Multi-coordinator Methods for Parallel Optimization", Ph.D. expected August 1995.

M. C. Ferris

- **Menglin Cao**, AFOSR Support: "Monotone Operators, Variational Inequalities and Polynomiality", Ph.D. expected December 1993.
- **Steven Dirkse**, NSF Fellow: "A system for formulating and solving complementarity problems", Ph.D. expected August 1994.
- **Stephen Billups**, NSF and Graduate School Support: "An Interior Point Sequential Programming Code and its Applications", Ph.D. expected August 1995.
- **Jeffrey Horn**, AFOSR and NSF Support: "Parallel solution of block structured problems", Ph.D. expected August 1996.

R. De Leone

- **Tia Newhall**, AFOSR Support: "Massively parallel solution of structured mathematical programs"

3.3 Papers and Technical Reports

O.L. Mangasarian

1. K.P. Bennett and O.L. Mangasarian, *Neural network training via linear programming*, in P. M. Pardalos (Editor), "Advances in Optimization and Parallel Computing", North Holland. Amsterdam 1992, 56-67.

2. K.P. Bennett, *Decision tree construction via linear programming*, Proceedings of the 4th Midwest Artificial Intelligence and Cognitive Science Society Conference 1992, 97-101.

3. K.P. Bennett O.L. Mangasarian, *Robust linear programming discrimination of two linearly inseparable sets*, Optimization Methods and Software 1, 1992, 23-34.

4. M.C. Ferris and O.L. Mangasarian, *Finite perturbation of convex programs*, Applied Mathematics and Optimization 23, 1991, 263-273.

5. M.C. Ferris and O.L. Mangasarian, *Minimum principle sufficiency*, Mathematical Programming B 57, 1992, 1-14.

6. M.C. Ferris O.L. Mangasarian, *Parallel constraint distribution*, SIAM Journal on Optimization 1, 1991, 487-500.

7. O.L. Mangasarian, *Mathematical programming musings*, in "History of mathematical programming", J.K. Lenstra, A.H.G. Rinnooy Kan and A. Schrijver, editors, North Holland. Amsterdam 1991, 107-113.

8. O.L. Mangasarian, *Global error bounds for monotone affine variational in equality problems*. Linear Algebra and Its Applications 174, 1992, 153-164.

9. O.L. Mangasarian and R.R. Meyer, *Proceedings of the Symposium on Parallel Optimization 2*, SIAM Journal on Optimization, Volume 1, Number 4, November 1991.

10. O.L. Mangasarian, *Convergence of iterates of an inexact matrix splitting algorithm for the symmetric monotone linear complementarity problem*, SIAM Journal on Optimization 1, 1991. 114-122.

11. O.L. Mangasarian and M.V. Solodov, *Nonlinear complementarity as unconstrained and constrained minimization*, University of Wisconsin, Computer Sciences Department Technical Report #1074, January 1992, Mathematical Programming B, to appear.

12. K.P. Bennett and O.L. Mangasarian, *Bilinear separation of two sets in n-space*, University of Wisconsin, Computer Sciences Department Technical Report #1109, August 1992. Computational Optimization and Applications, submitted.

13. Z.-Q. Luo, O.L. Mangasarians, J. Ren and M.V. Solodov, *New error bounds for the linear complementarity problem*, University of Wisconsin, Computer Sciences Department Technical Report #1112, September 1992, Mathematics of Operations Research, submitted.

14. K.P. Bennett and O.L. Mangasarian, *Multicategory discrimination via linear programming*. University of Wisconsin, Computer Sciences Department Technical Report #1127. August 1992, Optimization Methods and Software, to appear.

15. O.L. Mangasarian, *Mathematical programming in neural networks*, University of Wisconsin, Computer Sciences Department Technical Report #1129, December 1992, ORSA Journal on Computing, invited submission.

16. W.N. Street, *Toward automated cancer diagnosis: an interactive system for cell feature extraction*, University of Wisconsin, Computer Sciences Department Technical Report #1052, October 1991.

17. W.H. Wolberg and O.L. Mangasarian, *Computer-designed expert systems for breast cytology diagnosis*, Analytical and Quantitative Cytology and Histology, to appear.

18. W.H. Wolberg, K.P. Bennett and O.L. Mangasarian, *Breast cancer prognosis by machine learning*, February 1993, submitted to Cancer.

19. W.N. Street, W.H. Wolberg and O.L. Mangasarian, *Nuclear feature extraction for breast tumor diagnosis*, University of Wisconsin, Computer Sciences Department Technical Report #1131, December 1992, IS&T/SPIE 1993 International Symposium on Electronic Imaging: Science and Technology, to appear.

20. O.L. Mangasarian, *Parallel gradient distribution in unconstrained optimization*, University of Wisconsin, Computer Sciences Department Technical Report #1145, April 1993.

21. O.L. Mangasarian and M. V. Solodov, *Serial and parallel backpropagation convergence via nonmonotone perturbed minimization*, University of Wisconsin, Computer Sciences Department Technical Report #1149, April 1993.

22. O.L. Mangasarian and J. Ren, *New error bounds for the linear complementarity problem*, University of Wisconsin, Computer Sciences Department Technical Report #1156, June 1993.

23. K.P. Bennett and O.L. Mangasarian, *Serial and parallel multicategory distribution*, University of Wisconsin, Computer Sciences Department Technical Report #1165, July 1993.

24. O.L. Mangasarian, *Error bounds for inconsistent linear inequalities and programs*, University of Wisconsin, Computer Sciences Department Technical Report #1166, July 1993.

25. M.C. Ferris and O.L. Mangasarian, *Parallel variable distribution*, University of Wisconsin, Computer Sciences Department Technical Report #1175, August 1993.

R.R. Meyer

1. J. Yackel and R.R. Meyer, *Minimum-Perimeter Domain Decomposition*, University of Wisconsin, Computer Sciences Department Technical Report #1078, Feb 1992, submitted to Operations Research.

2. R. Clark, J. Kennington, R.R. Meyer, and M. Ramamurti, *Generalized Networks: Parallel Algorithms and an Empirical Analysis*, ORSA Journal on Computing 4, 1992, 132-145.

3. G. Schultz and R.R. Meyer, *A Structured Interior Point Method*, SIAM J. on Optimization 1, 1991, 583-602.

4. J. Yackel and R.R. Meyer, *Optimal Tilings for Parallel Database Design*, in P. M. Pardalos (Editor), "Advances in Optimization and Parallel Computing", North Holland, Amsterdam 1992, 293-309.

5. S. Ghandeharizadeh, R.R. Meyer, G. Schultz, and J. Yackel, *Optimal Balanced Partitions and a Parallel Database Application*, ORSA Journal on Computing, 5, 1993, 151-167.

6. S. Ghandeharizadeh, R.R. Meyer, G. Schultz, and J. Yackel, *Optimal Processor Assignment for Parallel Database Design*, in Proceedings of the Fifth SIAM Conference on Parallel Processing for Scientific Computing, 1992.

7. R.J. Chen, J. Yackel and R.R. Meyer, *A Genetic Algorithm for Diversity Minimization and Its Parallel Implementation*, in Proceedings of the International Conference on Genetic Algorithms, Stephanie Forrest, ed., Morgan Kaufmann Publishers, 1993.

8. R.R. Meyer and J. Yackel, *Large-Scale Diversity Minimization via Parallel Genetic Algorithms*, to appear in Proceedings of the Conference on Large-Scale Optimization, 1993.

9. R. De Leone, R.R. Meyer, S. Kontogiorgis, A. Zakarian, and G. Zakeri, *Coordination in Coarse-Grained Decomposition*, submitted to Proceedings of Symposium on Parallel Optimization 3, 1993.

1. K.P. Bennett, M. C. Ferris and Y. E. Ioannidis, *A genetic algorithm for database query optimization*, Proceedings of the Fourth International Conference on Genetic Algorithms and Applications, Morgan Kaufman, San Mateo, California 1991.

2. J.V. Burke, M.C. Ferris, and M. Qian, *On the Clarke subdifferential of the distance function to a closed set*, Journal of Mathematical Analysis and its Applications, 166, 1992, 199-213.

3. M.C. Ferris and M. Vlach, *Scheduling with earliness and tardiness penalties*, Naval Research Logistics Quarterly, 39, 1992, 229-245.

4. E.J. Anderson and M.C. Ferris, *Genetic algorithms for combinatorial optimization: The assembly line balancing problem*, Management Studies Research Paper 11/91, Engineering Department, University of Cambridge, 1991, ORSA Journal on Computing, to appear.

5. J.V. Burke and M.C. Ferris, *Weak sharp minima in mathematical programming*, University of Wisconsin, Computer Sciences Department Technical Report #1050, SIAM Journal on Control and Optimization, to appear.

6. M. Cao and M.C. Ferris, *An interior point algorithm for monotone affine variational inequalities*, University of Wisconsin, Computer Sciences Department Technical Report #1101. Journal Optimization Theory and Applications, to appear.

7. J. Eckstein and M.C. Ferris, *Operator splitting methods for monotone linear complementarity problems*, Thinking Machines Corporation Technical Report # 239, 1992.

8. M.C. Ferris, *The linear complementarity problem*, Bulletin of the American Mathematical Society, 28, 1, 1993,169-175.

9. M.C. Ferris, *Parallel constraint distribution for convex quadratic programs*, University of Wisconsin, Computer Sciences Department Technical Report #1009, 1991, Mathematics of Operations Research, to appear.

10. M.C. Ferris and A.B. Philpott, *On affine scaling and semi-infinite programming*, Mathematical Programming, 56, 3, 1992, 361-364.

11. M.C. Ferris and O.L. Mangasarian, *Error bounds and strong upper semicontinuity for monotone affine variational inequalities*, University of Wisconsin, Computer Sciences Department Technical Report #1056, November 1991, Annals of Operations Research, to appear.

12. M. Cao and M.C. Ferris, *A pivotal method for affine variational inequalities*, University of Wisconsin, Computer Sciences Department Technical Report #1114, 1992, submitted to Mathematics of Operations Research.

13. M.C. Ferris and S. Lucidi, *Nonmonotone stabilization methods for nonlinear equations*, Journal of Optimization Theory and Applications, to appear.

14. M.C. Ferris and O.L. Mangasarian, *Parallel variable distribution*, University of Wisconsin, Computer Sciences Department Technical Report #1175, 1993, submitted to SIAM Journal on Optimization.

15. J.V. Burke and M.C. Ferris, *A Gauss-Newton method for convex composite optimization*, University of Wisconsin, Computer Sciences Department Technical Report #1176, 1993, submitted to Mathematical Programming.

16. S.P. Dirkse and M.C. Ferris, *The path solver: A non-monotone stabilization scheme for mixed complementarity problems*, University of Wisconsin, Computer Sciences Department Technical Report #1179, 1993, submitted to Optimization Methods and Software.

17. S.C. Billups and M.C. Ferris, *Convergence of infeasible interior-point algorithms from arbitrary starting points*, University of Wisconsin, Computer Sciences Department Technical Report #1180, 1993, submitted to SIAM Journal on Optimization.

R. De Leone

1. R. De Leone and T. H. Ow, *Parallel implementation of Lemke's algorithm on the hypercube*. ORSA Journal on Computing 3, 1991, 56-62.

2. R. De Leone, R. Jain and M. Rim, *Optimal resource allocation and binding in High-Level synthesis*, Proceedings of the 29th ACM/IEEE Design Automation Conference, June 1992. 120–123

3. R. De Leone and M.A. Tork Roth, *Serial and Massively Parallel SOR Algorithms for Large-Scale Engineering Problems*, COAL Bulletin 20, 1992, 20-31.

4. R. De Leone, M. Gaudioso and M.F. Monaco, *Nonsmooth optimization methods for parallel decomposition of multicommodity flow problems*, Annals of Operations Research, 44, 1993.

5. R. De Leone and M.A. Tork Roth, *Massively Parallel Solution of Quadratic Program via Successive Overrelaxation*, Concurrency Practice and Experience, to appear.

6. R. De Leone, R. Jain and K. Straus, *Solution of multiple choice knapsack problems encountered in high-level synthesis of VLSI circuits*, International Journal of Computer Mathematics, 47. 1993, 163–176.

7. B. Narendran, R. De Leone and P. Tiwari, *An implementation of the ϵ-relaxation algorithm on CM-5*, Proceedings of Symposium on Parallel Algorithms and Architectures, 1993, 183–192.

8. R. Cerulli, R. De Leone and G. Piacente, *A modified auction algorithm for the shortest path problem*, Optimization Methods & Software, to appear.

9. A. Mujumdar, M. Rim, R. Jain and R. De Leone, *BINET: An Algorithm for Solving the Binding Problem*, International Conference on Computer Design, 1994, to appear

10. M. Rim, A. Mujumdar, R. Jain and R. De Leone, *Optimal and heuristic algorithms for the binding problem*, IEEE Transaction on VLSI Systems, to appear.

11. R. De Leone, R. Meyer, S. Kontogiogis, A. Zakarian and G. Zakeri, *Coordination in coarse-grain decomposition*, Submitted to *Siam Journal on Optimization*

12. J. Deasy, T. Holmes, T. Mackie and R. De Leone, *Coplanar beam weight optimization: Electrostatic model and iterative adjustement*, XIth International Conference on Computer Radiation Therapy, 1994, to appear

13. J. Deasy, T. Holmes, T. Mackie and R. De Leone, *Beam weight optimization using the MINOS coputer code*, XIth International Conference on Computer Radiation Therapy. 1994. to appear

3.4 Talks

O.L. Mangasarian

1. *Mathematical programming in neural networks and medical diagnosis*, Stanford University, Stanford November 1991.

2. *Diagnostic neural networks via linear programming*, California State University, Los Angeles March 1992.

3. (with K.P. Bennett) *Linear programming training of neural networks*, TIMS/ORSA Joint National Meeting, Orlando April 1992.

4. (with M. C. Ferris) *Parallel constraint and variable distribution*, Fourth SIAM Conference on Optimization, Chicago May 1992.

5. *Unconstrained minimization, duality and error bounds for nonlinear complementarity problems*, University of Rome, Rome September 1992.

6. *Approximate separation of sets via mathematical programming*, First Biennial Soviet-Italian Conference on Methods and Applications of Mathematical Programming, Cetraro, Italy September 1992.

7. (with K.P. Bennett) *Bilinear and multicategory separation via mathematical programming*, ORSA/TIMS Joint National Meeting, San Francisco November 1992.

8. *Mathematical programming in neural networks*, RAND Corporation, Santa Monica, CA March 1993.

9. *Neural networks via mathematical programming*, University of California at San Diego, La Jolla, CA March 1993.

10. (with M.C. Ferris) *Error bounds for affine variational inequalities*, TIMS/ORSA Joint National Meeting, Chicago May 1993.

11. (with M.V. Solodov) *Nonlinear complementarity as unconstrained and constrained minimization*, TIMS/ORSA Joint National Meeting, Chicago May 1993.

12. (with M.C. Ferris) *Parallel variable distribution in optimization*, TIMS/ORSA Joint National Meeting, Chicago May 1993.

R.R. Meyer

1. *Large Scale Multicommodity Transportation Problems*, Joint Operations Research/Artificial Intelligence Workshop on Transportation Planning, Pittsburgh October 1991
2. *Task Balancing in Parallel Computation via Multicommodity Flows*, TIMS/ORSA Joint National Meeting, Anaheim November 1991
3. *Optimal Tilings in Parallel Computation*, Universidad Simon Bolivar–Caracas, Venezuela December 1991
4. *Parallel Computing in Large-Scale Optimization*, Computer Science and Operations Research Conference, Williamsburg January 1992
5. *Network Models for Domain Decomposition*, TIMS/ORSA Joint National Meeting, Orlando April 1992.
6. *Minimizing Communication in Domain Decomposition via Minimum-Perimeter Tiling*, Fourth SIAM Conference on Optimization, Chicago May 1992.
7. *Optimal Tilings for Parallel Domain Decomposition and Database Design*, Technical University, Munich, Germany May 1992.
8. *Parallel Barrier-Based Algorithms for Multicommodity Flows*, Polytechnic University of Madrid. Madrid, Spain September 1992
9. *Large-scale parallel domain decomposition*, TIMS/ORSA Joint National Meeting, San Francisco November 1992.
10. *Network methods for parallel domain decomposition*, First Panamerican Workshop in Applied and Computational Mathematics, Caracas, Venezuela January 1993.
11. *Large-Scale Optimal Domain Decomposition*, Conference on Large Scale Optimization, Gainsville February 1993.
12. *Coarse-Grain Decomposition of Block-Structured Optimization Problems*, DIMACS Workshop on Future Directions for Parallel Optimization April 1993.
13. *Parallel Algorithms for Large-Scale Domain Decomposition* , ORSA/TIMS Joint National Meeting May 1993.
14. *A Genetic Algorithm for Diversity Minimization and Its Parallel Implementation* , Fifth International Conference on Genetic Algorithms July 1993.
15. *Parallel Genetic Algorithms for Large-Scale Nonconvex Network Optimization* , Netflow93 October 1993.
16. *A Parallel Genetic Algorithm for a Nonconvex Assignment Problem* , ORSA/TIMS Joint National Meeting November 1993.

M. C. Ferris

1. *Pivotal methods for affine variational inequalities*, Dept. of Mathematics, University of Washington, Seattle November 1991.
2. *Pivotal methods for generalized complementarity problems*, TIMS/ORSA Joint National Meeting, Anaheim November 1991
3. *Parallel constraint distribution*, Dept. of Operations Research, Stanford University, Stanford November 1991.
4. (with S.P. Dirkse) *Solving Complementarity Problems via GAMS*, Conference on Computational Economics, University of Texas at Austin May 1992.
5. *Parallel Constraint and Variable Distribution*, Fourth SIAM Conference on Optimization, Chicago May 1992.
6. *Monotone Operator Splitting and Linear Complementarity Problems*, Fourth SIAM Conference on Optimization, Chicago May 1992.
7. *Solving Complementarity Problems via GAMS*, Dept. of Mathematics, University of Washington, Seattle July 1992.
8. *Variational Inequalities and Convex Composite Optimization*, TIMS/ORSA Joint National Meeting, San Francisco November 1992.
9. *Pivotal Methods for Affine Variational Inequalities*, IASI, Roma, Italy January 1993.
10. *Genetic Algorithms in Optimization*, Engineering Department, University of Roma, Roma. Italy January 1993.
11. *Variational Inequalities and CPLIB*, Systems Engineering Department, University of Roma. Roma, Italy January 1993.
12. *Robust Solution of Mixed Complementarity Problems*, Judge Institute of Management Studies. Cambridge University, England January 1993.
13. *Robust Solution of Mixed Complementarity Problems*, Rutherford Laboratories, Oxford, England January 1993.
14. (with O.L. Mangasarian) *Error bounds for affine variational inequalities*, TIMS/ORSA Joint National Meeting, Chicago May 1993.
15. (with O.L. Mangasarian) *Parallel variable distribution in optimization*. TIMS/ORSA Joint National Meeting, Chicago May 1993.
16. (with O.L. Mangasarian) *Parallel variable distribution*, Symposium on Parallel Optimization III, Madison July 1993.

R. De Leone

1. *Successive Over-Relaxation (SOR) Methods for Multicommodity Transportation Problems*, Joint Operations Research/Artificial Intelligence Workshop on Transportation Planning, Pittsburgh October 1991

2. *General Parallel Decomposition Method for Multicommodity Network Optimization Problems*, TIMS/ORSA Joint National Meeting, Anaheim November 1991

3. *Optimal resource Allocation and Binding of Non-Pipelined Design*, TIMS/ORSA Joint National Meeting, Anaheim November 1991

4. *Nonsmooth Optimization Methods for Parallel Decomposition of Multicommodity Flow Problems*, ORSA/CSTS meeting, Williamsburg January 1992

5. *Approcci Poliedrali per la Soluzione di Problemi di Programmazione Intera*, University of Roma, Rome, Italy January 1992

6. *Optimal Resource Allocation and Binding of Non-Pipelined Design*, University of Salerno. Salerno Italy January 1992

7. *Solution of Multicommodity Network Flow Problems Using Decomposition Techniques*, TIMS/ORSA Joint National Meeting, Orlando April 1992.

8. *Parallel Solution of Extremely Large Quadratic Programs*, University of Camerino, Camerino. Italy June 1992

9. *A Massively Parallel Implementation of the Epsilon-Relaxation method*, TIMS/ORSA Joint National Meeting, San Francisco November 1992.

3.5 Outside Visitors and Speakers

- **Prof. Geoffrey Hinton**, University of Toronto, October 8-10, 1991 , Shape Recognition in Neural Networks: Using Adaptive Elastic Models to Recognize Hand-Printed Characters
- **Prof. Evgeny Golshtein**, USSR Academy of Sciences, October 10, 1991 , Parallel Constraint and Variable Distribution in Optimization
- **Prof. Leslie Valiant**, Harvard University, October 15-17, 1991 , Learning with Discrete Neural Models
- **Maj. Michael Ackley and Alan Whisman**, Scott AFB, October 30-31, 1991
- **Dr. Raffaele Cerulli**, University of Salerno, Italy, January 1992-May 1992
- **Dr. David Johnson**, AT&T Bell Labs, April 15-16, 1992 , The Traveling Salesman Problem
- **Prof. Richard W. Cottle**, Stanford University, May 14-16, 1992 , Some Open Questions on Matrix Classes in the Linear Complementarity Problem
- **Prof. Luigi Grippo**, University of Rome, Italy, May 13-16, 1992 , Differentiable Exact Penalty Functions: An Overview
- **Dr. Domenico Conforti**, University of Calabria, Italy, May 13-16, 1992
- **Dr. Ilya Dikin**, Siberian Energy Institute, Russia, May 19, 1992 , The convergence of sequence of dual variables
- **Dr. Danny Ralph**, Cornell University, July 15-22, 1992 , Decomposition of Discrete-Time Optimal Control Problems
- **Prof. George F. Corliss**, Marquette University and Argonne National Laboratories, October 20, 1992 , The Functionality of ADIFOR
- **Prof. Klaus Ritter**, Technical University of Munich, September-October, 1992 , A Superlinearly Convergent Algorithm for Singular-Point Minimization
- **Prof. Rong-Jaye Chen**, Department of Computer Science and Information Engineering, National Chiao Tung University, Taiwan, September 1992-August 1993 , A Systolic Design for Dynamic Programming
- **Prof. B. T. Polyak**, Institute for Control Science, Moscow, Russia November 19, 1992 . Multilinear programming
- **Prof. Norman Curet**, UW–Stevens Point December 3, 1992 , On the Incremental Primal-Dual Algorithm for Network Optimization
- **Prof. Thomas F. Rutherford**, University of Colorado, December 10-11, 1992 , Sequential Joint Maximization
- **Dr. Domenico Conforti**, University of Calabria, Italy, January 1993-December 1993
- **Prof. Jim Burke**, University of Washington, February 8-11, 1993 , Variational Properties of the Spectral Abscissa and the Spectral Radius for Analytic Matrix-Valued Mappings

- **Dr. Jonathan Eckstein**, Thinking Machines Corporation, March 16-19, 1993 , A Branch-and-Bound Method for Mixed Integer Programming on the CM-5
- **Dr. Roberto Musmanno**, University of Calabria, Italy, April 7-9, 1993
- **Dr. Edward Anderson**, University of Cambridge, England, May 5-29, 1993 , Mechanisms for local search: Is first improving best?
- **Symposium on Parallel Optimization 3**: Twenty-one invited presentations were given at this international symposium organized by CPO and held in Madison 7-9 July, 1993. Details are given in the next section of this report.

3.6 Symposium on Parallel Optimization 3

Twenty-one invited presentations were given at this international symposium organized by the Center for Parallel Optimization and held in Madison 7-9 July, 1993. Refereed proceedings will be published as a special issue of the SIAM Journal on Optimization in 1994. An alphabetical list of speakers is given below.

- Dr. Kristin P. Bennett
  Dept. of Operations and Info. Mgmt.
  University of Connecticut
  368 Fairfield, U-41
  Storrs, CT 06269

  Professor Olvi L. Mangasarian
  Computer Science Department
  1210 W. Dayton Street
  University of Wisconsin
  Madison, WI 53706

  "Parallel Multicategory Discrimination"

- Professors Robert R. Meyer and Renato De Leone
  Computer Science Department
  1210 W. Dayton Street
  University of Wisconsin
  Madison, WI 53706

  "Coordinating Mechanisms in Coarse-Grained Decomposition"

- Professor John E. Dennis
  Center for Research on Parallel Computing
  Fondren Library/CITI
  Rice University
  Houston, Texas 77005

  "Multidisciplinary Optimization"

- Dr. Jonathan Eckstein
  Thinking Machines Corporation
  245 First Street
  Cambridge, MA 02142

  "Parallel Branch-and-Bound Algorithms for General Mixed Integer Programming on the CM-5"

- Professors Michael C. Ferris and Olvi L. Mangasarian
  Computer Sciences Department
  1210 W. Dayton Street
  University of Wisconsin
  Madison, WI 53706

  "Parallel Variable Distribution"

- Professor Alexei A. Gaivoronski
  ITALTEL
  Central Research Laboratories
  I-20019 Castelletto di Settimo
  Milanese (MI), Italy

  "Convergence of Parallel Backpropagations Algorithm for Neural Networks"

- Professor Luigi Grippo
  Univ. degli Studi di Roma "La Sapienza"
  Dipartimento di Infor. e Sistemistica
  Via Buonarroti 12
  00185 Roma, Italy

  "A Class of Unconstrained Minimization Methods for Neural Network Training"

- Professor T. C. Hu
  Computer Science Department
  University of California at San Diego
  La Jolla, CA 92093

  "Parallel Dynamic Adaptive Searching Algorithms"

- Dr. Tom Luo
  Communications Research Laboratory
  Faculty of Engineering
  McMaster University
  1280 Main Street West
  Hamilton, Ontario L8S 4K1, Canada

  Professor Paul Tseng
  Department of Mathematics, GN-50
  University of Washington
  Seattle, Washington 98195

  "Convergence Analysis of Backpropagation Algorithm for Neural Networks with Arbitrary Error Functions"

- Mr. Rich Maclin and Professor Jude Shavlik
  Computer Science Department
  1210 W. Dayton Street
  University of Wisconsin
  Madison, WI 53706

  "Optimizing Objective Functions that Have Many Local Minima: Combining Multiple Neural Networks Trained in Parallel"

- Professor Olvi L. Mangasarian
  Computer Science Department
  1210 W. Dayton Street
  University of Wisconsin
  Madison, WI 53706

  "Serial and Parallel Backpropagation Convergence via Nonmonotone Perturbed Minimization"

- Professors Sanjay Mehrotra and Robert Fourer
  Department of Industrial Engineering
  and Management Sciences
  Northwestern University
  Evanston, IL 60208

  "Solving Large Sparse Linear Programs Using the CM-2"

- Dr. Jorge J. Moré
  Mathematics and Computer Science Div.
  Argonne National Laboratory
  9700 South Cass Avenue
  Argonne, IL 60439

  "On the Evaluation of Large-Scale Problems on Serial and Parallel Machines"

- Professor John M. Mulvey
  Department of Civil Engineering
  Princeton University
  Princeton, New Jersey 08544

  "Testing a Distributed Scenario Decomposition Method for Large Stochastic Programs"

- Professor Jong-Shi Pang
  Department of Mathematical Sciences
  The Johns Hopkins University
  Baltimore, Maryland 21218

  "Serial and Parallel Computation of Karush-Kuhn-Tucker Points via Nonsmooth Equations"

- Professor Dr. Klaus Ritter
  Institut für Mathematik und Statistik
  Technische Universität Munchen
  Arcisstrasse 21
  8000 Munchen 2, Germany

  "A Stochastic Method for Constrained Global Optimization"

- Professor J. Ben Rosen
  Computer Science Department
  4-192 EE/CSci Building
  University of Minnesota
  200 Union Street S.E.
  Minneapolis, Minnesota 55455

  "Large-Scale Nonlinearly Constrained Optimization on a 1024-Processor nCUBE"

- Drs. Alan Whisman and Erick Wikum
  U.S. Air Force
  HQ MAC/XPY
  Scott AFB, IL 62225

  "Robust Estimates for the Airlift Mobility Command Channel System"

- Dr. Margaret H. Wright
  ATT Bell Laboratories
  Room 2C-462
  600 Mountain Avenue
  Murray Hill, NJ 07974

  "Exploiting Parallelism in Solving Large-Scale Least-Squares Problems from System Identification Programming"

- Dr. Xiru Zhang
  Thinking Machines Corporation
  245 First Street
  Cambridge, MA 02142

  "Massively Parallel Computing in Protein Structure Prediction and Time Series Analysis"

- Professor Stavros Zenios
  Department of Decision Sciences
  The Wharton School
  University of Pennsylvania
  Philadelphia, PA 19104

  "Scalable Massively Parallel Algorithms for Robust Optimization"